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U.S. EPA, REGION 10
HW-106

RCRA PERMITS SECTION

FROM:ROBERT FARRELL

SUBJECT:PNOCO OIL SPILL, Pier 91-- REVIEW:
PRELIMINARY HYDROGEOLOGIC ASSESSMENT REPORT, NOV. 22, 1989;
PHASE I REMEDIAL INVESTIGATION, JANUARY 5, 1990;
PHASE I REMEDIAL INVESTIGATION, JULY 5, 1990;
INTERIM PRODUCT EXTRACTION SYSTEM, REMEDIAL ACTION PLAN, JULY 26
1990
ANNUAL PROGRESS REPORT, MARCH 5, 1992;

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A diesel oil release was identified from a pipeline located on Pier 91 adjacent to a pond called both the North Pond and Lake Jacobs. From 1988 until 1992 several investigations were undertaken to define the extent of the LNAPL release, to define the hydrogeology, and to determine the best interim measures to be applied. During the investigations, LNAPL was reported in MW-3, in a test pit under the pipeline, and in MW-104. In the annual report of March, 1992 floating product was reported in EW-1, MW-3, and MW-102. It was speculated that the LNAPL identified in MW-104 represented a different plume.

The geologic cross sections (figure 3 and 4) in the remedial investigation report of July 5, 1990 indicate a sand or gravelly sand over a layer of sandy gravel. This in turn overlies another layer of gravelly sand/sand. The layer of sandy gravel thickens to the north toward MW-104 (at the south west corner of building W-39). The east and west sides of Pier 91 are marked by what are called bulkheads. It is not clear if these bulkheads are sheet pile walls or another type of structure. Various reports suggest these bulkheads have very low permeability relative to the aquifer and act as barriers to ground water flow and LNAPL migration. It is stated that the east bulkhead acts to dam the LNAPL on the west side of the bulkhead (pg. 1, July 26, 1990 report). Given the importance of these bulkheads to control the distribution of LNAPL, it would have seemed important to have included some conclusive evidence indicating whether or not the bulkheads actually are restrictions to LNAPL or ground water movement. No real data is presented in any report. Even the pump test done on MW-6 (July 26, 1990 report) was interpreted to show a recharge boundary at some distance from the pumping well rather than as showing a restrictive boundary as would be consistent with a low permeable boundary of the bulkheads.

The hydraulic conductivity of the sediments is not reported in any of the documents reviewed. The descriptions of the sediments

would suggest the hydraulic conductivity of the sediments should be fairly high. The transmissivity reported from the pump test is 0.11 ft. sq./min. (page 5, July 26, 1990, Interim product extraction system). The transmissivity was converted to hydraulic conductivity and is reported as being $5.6E-3$ cm/sec. It is not clear that the transmissivity from this test can be directly converted to hydraulic conductivity as was done in the report because of the nature of the test and the unknown depth of the aquifer. The storage coefficient is reported to be $6E-6$. The report indicated the results show the aquifer is highly confined. There is no evidence in any of the boring logs or geologic cross sections of a confining layer. It would also be very difficult for an LNAPL to penetrate the very impermeable sediments necessary to provide this extent of confinement suggested by the low storage coefficient derived from the test. These findings disagree with such statements as those on page 1 of the July 26, 1990 which indicate the "presence of the floating diesel hydrocarbon on the water table...". All the evidence from the boring logs and the geologic cross sections indicate the shallow aquifer is a water table aquifer in high to moderately high permeable sediments.

The ground water contour maps are reported for several dates. In each contour map the ground water flow direct is generally down the axis of Pier 91 parallel to the bulkheads of either side of the pier. From these maps it would appear the bulkheads act to constrain the ground water flow and prevent any interconnection of Lake Jacobs with the aquifer.

PUMP TEST REVIEW

The original data logs for the pump test are not available for review. Such data as a step drawdown test, the logs of the discharge rates versus time taken during the pump test, the record of the tidal changes in the seas and in the wells during the test (plotted at the same scale as the time drawdown data for the pump well and each observation well), the elevations of Lake Jacobs during the test, etc. are missing or were not taken. If this data was collected, it was not used or presented in any of the reports to support the results of the pump test. If this data was not collected, the pump test was severely compromised and, as a result, is probably useless.

The data collected from MW-2 is marginal at best. From the text describing the test there apparently was no identifiable response of the well during the actual pumping of MW-6. It is not clear how suddenly all this confusion can be resolved during the recovery phase. Given that the reported response of MW-2 is within the observed response of the wells to tidal changes, it seems likely that the response is related to tidal change and has nothing to do with the pump test at all. The hydrographs of the tidal changes in the sea at Pier 91 and the response of the other observation wells would have aided in interpreting the results.

Because of the uncertainty of the data from MW-2 during the pump test any results based on the use of data from MW-2 are suspect.

The data from figure 8 in the July 26, 1990 report for the pumping well MW-6 was replotted on semi-log paper (figure 1 attached). The data shows three breaks in the curve at about 40 minutes, 400 minutes, and some time after 1000 minutes into the test. Each of these breaks probably corresponds to changes in the pumping rate. In each case the pump rate appears to have returned to near its original rate. After each break the straight line continues to the next break. There is no evidence from the plot of the data that a recharge boundary or any other type of boundary was encountered during the pump test. Without a log of the pumping rate versus time taken during the test is not possible to determine if these breaks in the curve are really caused by changes in pumping rates or not. The transmissivities determined from these straight line segments would be at least an order of magnitude lower than the transmissivity that is suggested in the report. Interpreting this semi-log plot does not consider the effects of partial penetration of the pumping well nor the resulting vertical flow paths necessary to reach such a short well screen. As an example, the pump test indicates that the water level was lowered 4 feet in MW-6 during the pump test. The lowering of the water level by this amount changes the strata contributing water to the well from the sandy gravel to the gravelly sand/sand below it. If the hydraulic conductivity of these materials are significant, there should have been a corresponding change in the drawdown curve for the well. No corresponding change is recorded in the data. Further, if the transmissivity of the sediments is as low as suggested by either the semi-log plot or that suggested in the reports and assuming that the aquifer is a phreatic aquifer, it would take 18 days or longer to see a meaningful response at a monitoring well 50 feet away from the pumping well. If the aquifer is a phreatic aquifer, the effects of delayed yield would have to be factored into the amount of time necessary to obtain a meaningful drawdown curve. To observe these effects for such a small pumping rate as was used in this test would require the observation wells to be very close and the pumping well or the test would have to be carried out for a very long time. Neither of these conditions have been met by this pump test.

REVIEW OF TIDAL DATA

Tidal curves are reported for MW-2 and MW-6 in the November 22, 1989 report. It is indicated that the maximum tidal change in the wells is about 0.24 feet. It is indicated that Lake Jacobs had virtually no tidal response. This lack of response of the pond is attributed to the isolation of the pond by bulkheads (pg. 3, July 26, 1990, Interim product extraction system, remedial action plan). The tidal fluctuations observed in the monitoring wells were considered sufficiently small that no corrections were made to any measured ground water levels collected in any of the studies. This

is apparently all that was gleaned from the tidal study reported in the available site studies.

The tidal curves for MW-2 and MW-6 in the November 22, 1989 report were reviewed. Both wells were monitored through two tidal cycles. These curves are unusual with respect to the changes in elevations between tidal cycles. From other tidal curves studied from the Puget Sound area (OCC-Tacoma, Burlington facility-Pier 91), one of the cycles in a 24 hour period is significantly higher and lower than the other cycle. Also unusual is the response of MW-2, located about 230' from the shore, which has a larger response and shorter lag time than MW-6 located only about 180' from the shore.

In order to use the tidal curves for determining the aquifer parameters, it is necessary to place the times at which high and low tides occur in the bay near Pier 91 on the tidal curves for MW-2 and MW-6. It is then possible to determine the lag times of the cycles in the ground water. Knowing the lag time, the distance to the shore, and the time between the peaks and troughs of the tidal cycles, it is possible to determine the conductance (T/S ratio) for each well. For MW-6 the T/S ratio ranges from 96.2 ft. sq./min. to 727 ft. sq./min. For MW-2 the T/S ratio ranges from 229 ft. sq./min. to 1854 ft. sq./min. From the geologic cross sections shown on figures 3 and 4, MW-2 has a longer section of sandy gravel than does MW-6. It makes sense that the conductance of MW-2 should be higher than at MW-6. The tidal efficiency of MW-2 is also higher than MW-6 even though MW-2 is located further from the shore than MW-6.

The geologic cross sections indicate the aquifer is a phreatic aquifer. No confining layer is indicated above the water table and the water table appears to move from one sediment to another without apparent deflection. There is considerable variation possible for the storage coefficient in a phreatic aquifer. The extreme range of values for the storage coefficients (S) would be from 0.2 to 0.001. Given this range of S, the transmissivity for the T/S ratios can be resolved. From the conductance ratios determined above, the transmissivity of the aquifer ranges from 260000 ft. sq./day down to 2600 ft. sq./day. No data is provided for the thickness of the aquifer in any report. If it is assumed that the aquifer is 50 feet thick, the hydraulic conductivity would range from 1.8 cm/sec. to $1.8E-2$ cm/sec. Such values of hydraulic conductivity are consistent with the descriptions of the sediments on the boring logs and geologic cross sections. If the storage reported from the pump test of $1E-6$ cm/sec. (pg. 5, July 26, 1990) is used to determine the hydraulic conductivity for the sediments, the hydraulic conductivity would range from $1.8E-5$ cm/sec. to $9.7E-7$ cm/sec. These values would not reflect the descriptions of the sediments in the logs and cross sections nor would these values be consistent with the response of the wells to the tidal changes and distances wells MW-2 and MW-6 are from the shore.

REVIEW OF GROUND WATER CONTOUR MAPS

Several ground water contour maps are presented in various reports. They all seem to show basically the same general direction of ground water flow to the south and slightly southeast. The contour maps prior to September, 1990 were based on water levels measured in wells 103, 102, 104, 101, 3, 2, 11, and 6. After September, 1990 EW-1 was added to the monitoring system. EW-1 is in close proximity to MW-3 and the bulkhead separating Pier 91 from the short fill area and Lake Jacobs. In December, 1990; April, 1991; and August, 1991 the water elevation of MW-3 is lower than the water elevation in EW-1. Only in January, 1992 was the elevation of MW-3 higher than EW-1. It is difficult to reconcile these differences in ground water elevations between MW-3 and EW-1 in light of the numerous statements in the reports that the bulkhead limits communications of ground water.

There is limited information on the elevation of Lake Jacobs. Where there is information on the contour maps (April 9, 1990, and July 11, 1990) Lake Jacobs is shown as being lower than the water levels in MW-3 and MW-2 (8.04' and 8.03' are the elevations of Lake Jacobs). On figure 7, in the July 26, 1990 report Lake Jacobs is reported as having consistently higher water elevations than the water elevation in well MW-3 (figure 7 hydrographs cover the period from April 9 to April 10, 1990). The data on the contour map for April 9, 1990 shows the water level in MW-3 as 8.54'. On figure 7 the water level of MW-3 is never above 8'. Both sets of data can not be correct.

Close contouring of the available ground water data shown on figure 10 (April, 1991) and figure 11 (August, 1991) in the March 5, 1992 annual report indicates there is a discharge point through the bulkhead near wells MW-3 and EW-1. There is not enough data on the January 2, 1992 map to contour the direction of ground water flow. The available data for January 2 suggests there is a discharge point through the bulkhead further south than on the earlier maps. Whether this is because of a higher elevation in Lake Jacobs or is caused by some other reason is not known.

The ground water data from the most recent report of March 5, 1992, with EW-1 data, suggests the bulkheads on the east side of Pier 91 are not significant barriers to ground water flow. The presense of EW-1 near the bulkhead and MW-3 shows there is detail in water elevations and, therefore, ground water flow that is being missed because there are not sufficient observation wells used to draw ground water contour maps.

The ground water contour maps provided in the Burlington reports for their site indicate MW-104 is down gradient of the their site. The LNAPL observed at MW-104 probably originates at the Burlington site.

CONCLUSIONS

The pump test on MW-6 was useless. The results presented in the reports are inconsistent with the geologic descriptions of the sediments, the occurrence of ground water on Pier 91, and the data available from the tidal monitoring curves. The model of a highly confined aquifer with a recharging boundary applied to analyzing the pump test data in the reports is inconsistent with the geology of the site. The pumping rate was much too small to have any significant effect on the aquifer any distance from the pumping well and the apparent response of MW-2 was probably confused with the tidal response of MW-2. None of the usual preliminary testing expected in preparation for a pump test appears to have been done. No slug tests were done to determine the hydraulic conductivity of the sediments and to estimate the transmissivity of the sediment. No attempt was made to determine the aquifer thickness. It is not known if a step draw down test was performed to determine the optimum pump rate. The plotting of the available data from the pumped well suggests there were variable pumping rates during the test.

There are not sufficient monitoring wells in the system to correctly contour the ground water nor to determine the direction of ground water flow. This lack of data is demonstrated by the addition of just one well, EW-1, to the system requiring a substantial change in the ground water flow direction to incorporate the data from this well into the ground water flow. The addition of just this one well does not support the conclusion presented in the reports that the bulkheads are a significant impediment to ground water flow. There has not been sufficient QA/QC of the data contained in the reports to insure the figures are consistent with the data.

The lack of response of Lake Jacobs to tidal changes was used to support the lack of interconnection between the pond and the aquifer through the bulkhead. No consideration appears to have been given in the reports of what should be expected from a surface body of water in a tidally active aquifer. The relative storage between the pond and the aquifer should suggest that there be very little if any response of the pond to tidal changes. Relative to the storage in the aquifer, the storage in the pond should appear nearly infinitely large. The lack of response of the pond to tidal changes will tell you nothing about the permeability of the bulkhead, the aquifer, nor the interconnection of the aquifer and the pond.

The LNAPL extraction system need rethinking to be effective in removing LNAPL. The way the system is structured and the lack of depression of the water table restricts the collection of the LNAPL to only those flow paths happening to intersect the well. No measurable depression of the water table is discernible from the available data. The extraction, as designed, does not enhance the

collection of LNAPL in any way. It is likely the LNAPL migration to MW-102 since 1988 and the decrease in LNAPL around MW-3 and EW-1 reflects only the elimination of the source and the migration of the LNAPL out of the area across the bulkhead into Lake Jacobs or into the short fill area.

Figures such as figure 2 in the July 26, 1990 report indicate the plume of LNAPL has migrated directly east from the source area at the pipeline to the east bulkhead at MW-3. The data from EW-1 and MW-3 would indicate this is the expected direction of migration of the LNAPL because the ground water flow is in this direction and not south down Pier 91 as suggested by the ground water contour maps in the reports.

Given the data provided in the reports and the additional reduction of the data done for this review, the following seems to fit the available data:

- 1)no significant removal of LNAPL has occurred as a result of operating the extraction system in the period September, 1990 to April, 1992;

- 2)LNAPL has migrated south and south east through the bulkhead and probably into Lake Jacobs and the short fill area;

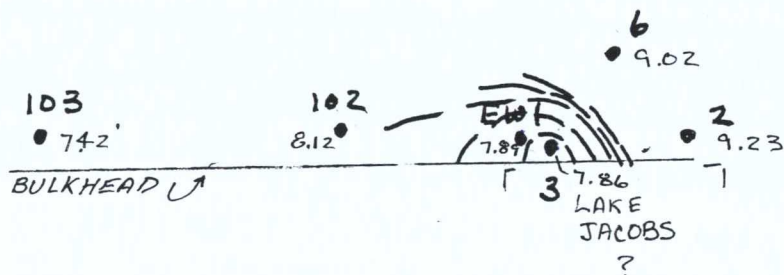
- 3)the source of LNAPL has probably been corrected;

- 4)the shallow aquifer is a relatively high yielding aquifer with high ground water velocities;

- 5)the LNAPL detected in MW-104 originates at the Burlington facility;

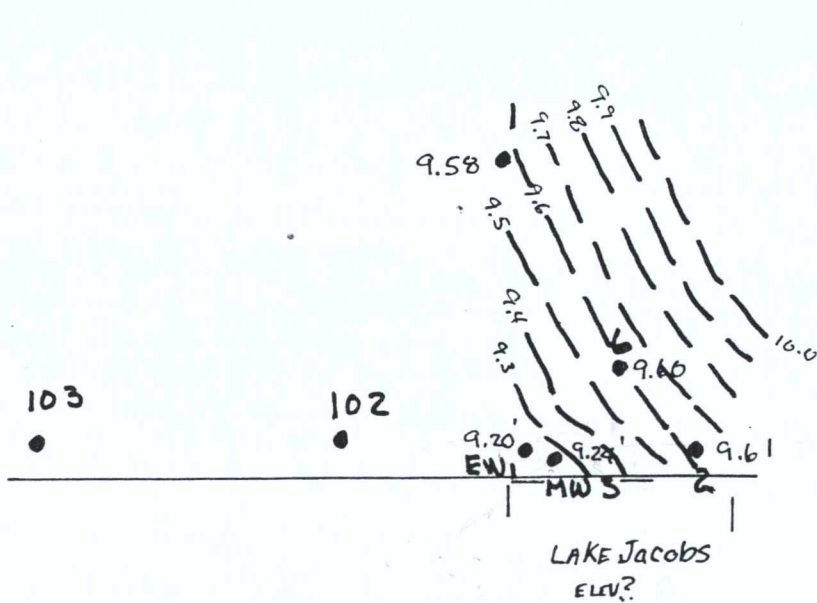
- 6)there are not enough monitoring wells installed during the various investigations to properly understand the direction of ground water flow; and

- 7)there were not sufficient periods of continuous water level monitoring to determine the correct directions of ground water flow.



11.17'
• 104

GROUND WATER
April 30, 1991



101
11.06'

• 104

JANUARY 2, 1992

$$Q = 0.30 \text{ gal/m} = 0.040 \text{ ft}^3/\text{m} \quad \Delta H = 3.11'$$

$$\textcircled{I} \quad T = \frac{2.3 Q}{4\pi h \Delta H} = \frac{(2.3)(.04)}{4\pi(3.11)} = 2.3 \times 10^{-3} \text{ ft}^3/\text{min}$$

$$= 35.3 \text{ gal/day/ft}$$

$$\textcircled{II} \quad T = \frac{(2.3)(.04)}{4\pi(.89)} = 8.22 \times 10^{-5} \text{ ft}^2/\text{min}$$

$$= 88.6 \text{ gal/day/ft}$$

$$u = \frac{r^2 S}{4Tt}$$

$$t = \frac{r^2 S}{4Tu}$$

$$= \frac{(50)^2 (1000)}{4(2.3 \times 10^{-3})(.01)}$$

$$r = 50'$$

$$S = ?$$

$$T = ?$$

$$u = .01$$

\textcircled{III}

$$S = 1000 \quad t = 2717 \text{ minutes}$$

$$45 \text{ hrs}$$

$$S = .001 \quad 27173 \text{ minutes}$$

$$452 \text{ hr}$$

$$18 \text{ days}$$

$$S = .01 \quad t = 180 \text{ days}$$

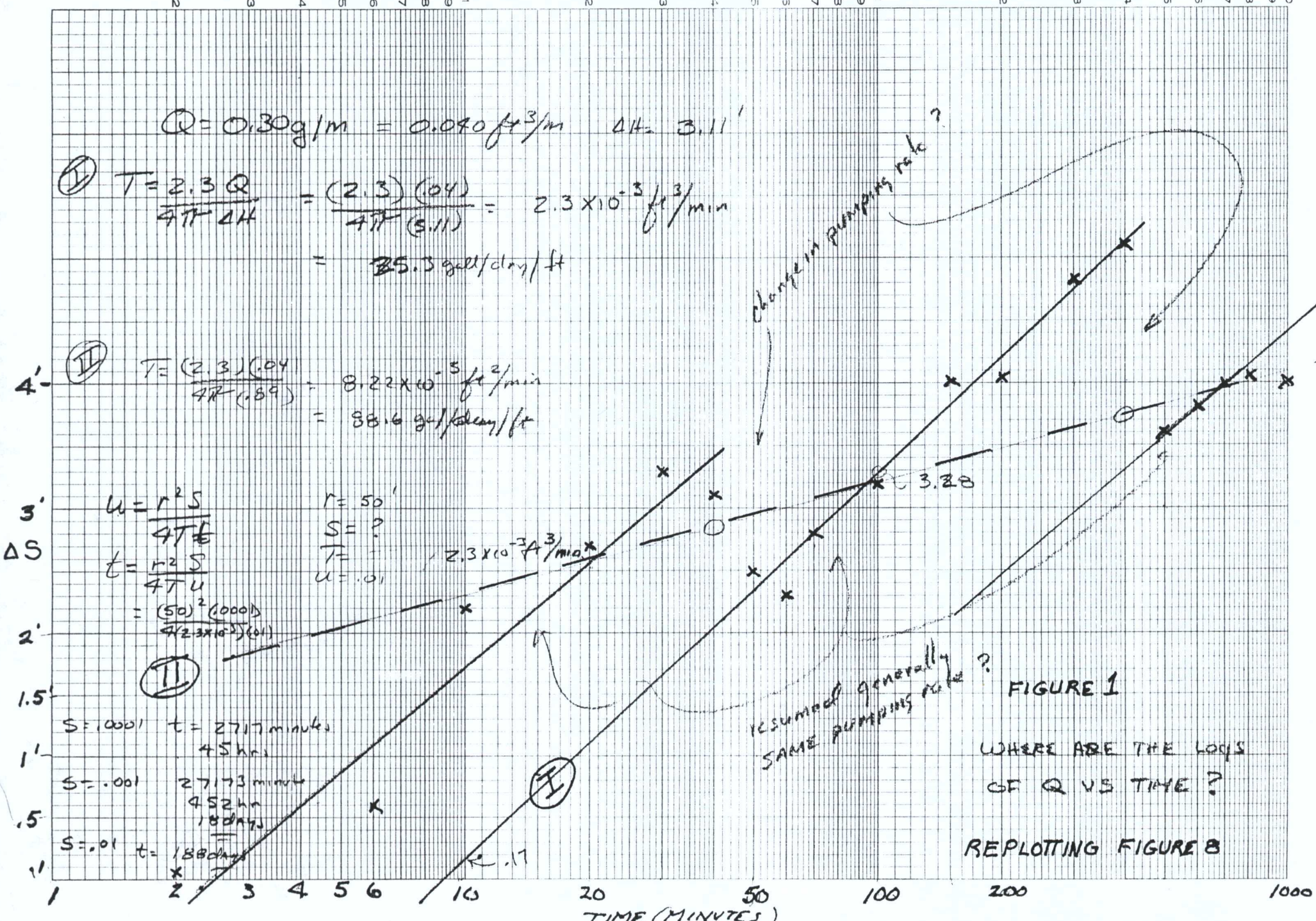


FIGURE 1

WHERE ARE THE LOGS
OF Q VS TIME?

REPLOTTING FIGURE 8